Interdisciplinary Pathways

An NSF Perspective on Sustainability Research

W. Lance Haworth
Director, NSF Office of Integrative Activities

Visioning the Future of Water-Energy Research
A Symposium Honoring Mark Shannon
University of Illinois at Urbana-Champaign
30 November 2010

Towards a Sustainable Human Future

Whether it's improving our health or harnessing clean energy, protecting our security or succeeding in the global economy, our future depends on reaffirming America's role as the world's engine of scientific discovery and technological innovation.

- President Barack Obama

Of all the challenges we face as a nation and as a planet, none is as pressing as the three-pronged challenge of climate change, sustainable development and the need to foster new and cleaner sources of energy.

- Office of Science and Technology Policy, Executive Office of the President

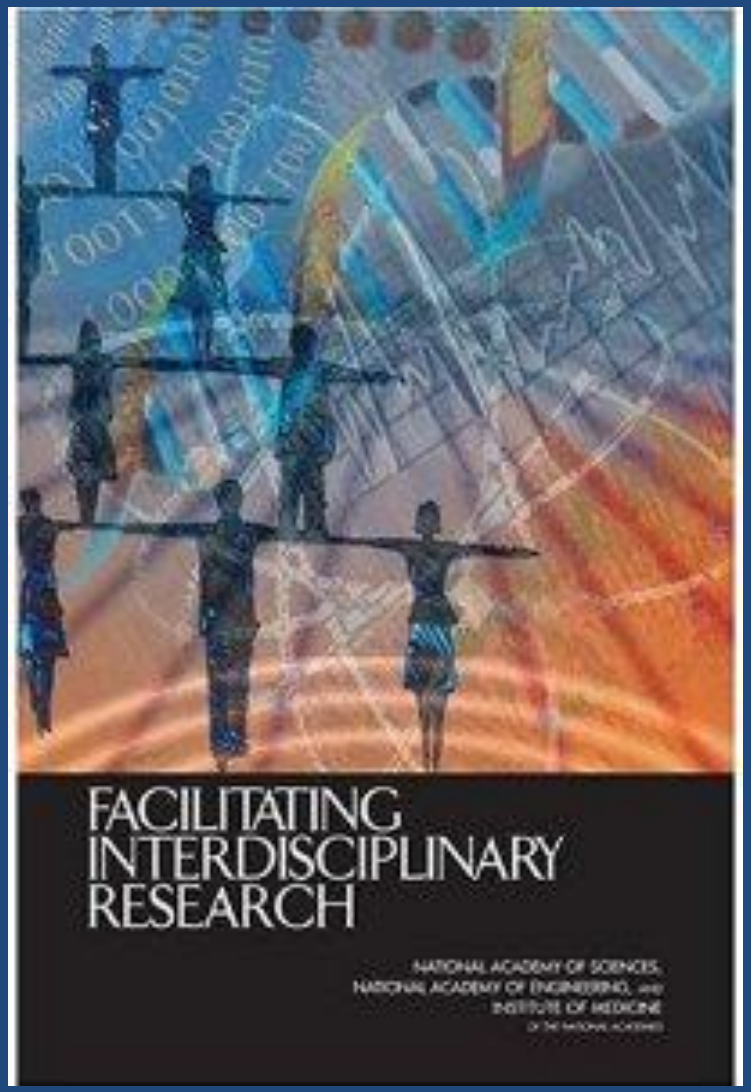
Outline

- Interdisciplinary Research
- Science and Technology Centers / Sustainability
- The NSF SEES Portfolio – Science, Engineering and Education for Sustainability
- An NSF Portal for IDR Proposals

From the NSF Strategic Plan

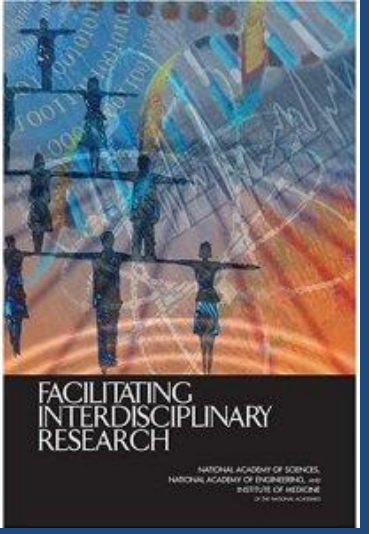
Discovery increasingly requires the expertise of individuals with different perspectives – from different disciplines and often from different nations -- working together to accommodate the extraordinary complexity of today's science and engineering challenges

The convergence of disciplines and the cross-fertilization that characterizes contemporary science and engineering have made collaboration a centerpiece of the science and engineering enterprise



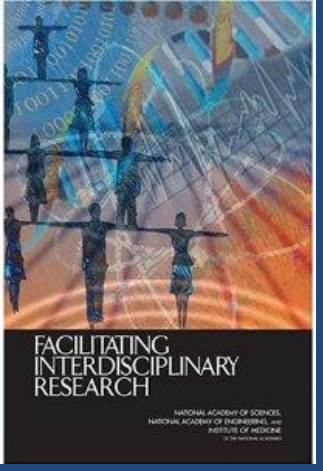
"**Interdisciplinary Research** can be one of the most productive and inspiring of human pursuits – one that provides a format for conversations and connections that lead to new knowledge."

Facilitating Interdisciplinary Research - NAS 2004



"Four powerful drivers towards interdisciplinary thinking"

- the inherent complexity of nature and society
- the desire to explore problems that are not confined to one discipline
- the need to solve societal problems
- the power of new technologies

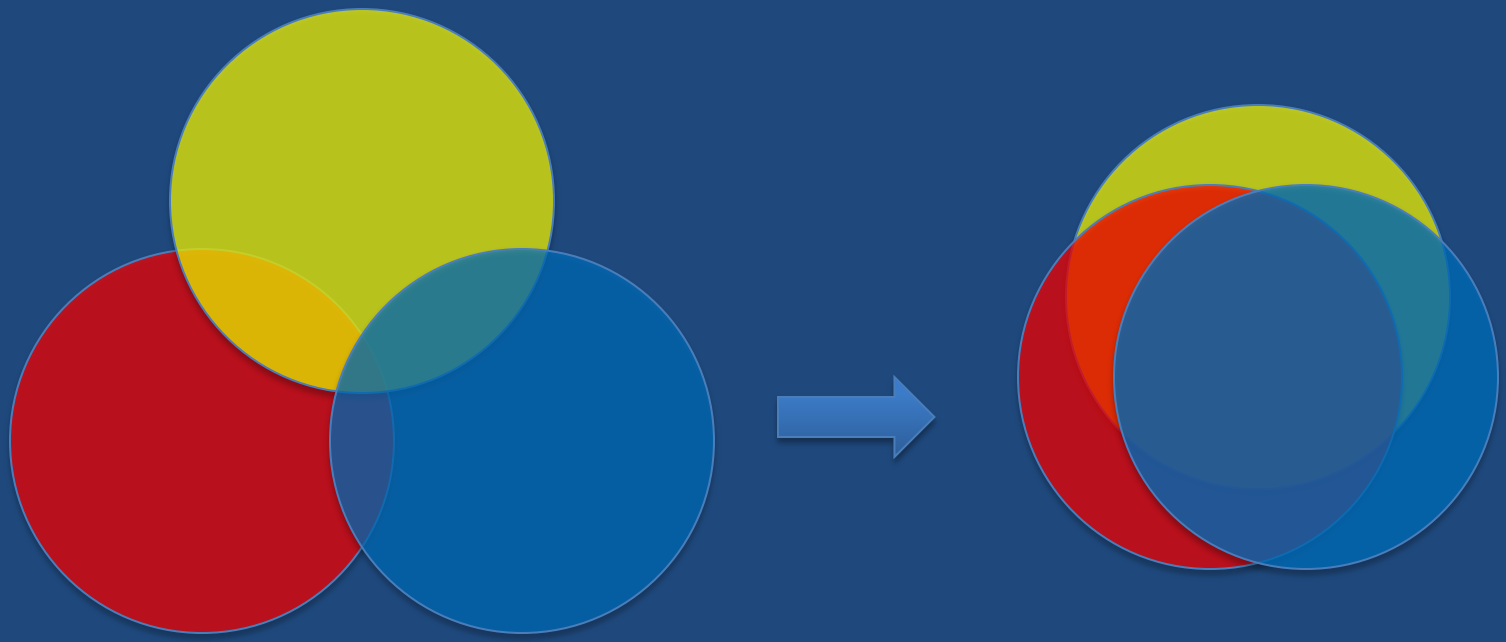


Challenges to Overcome

"The characteristics of IDR pose special challenges for funding organizations that wish to support it"

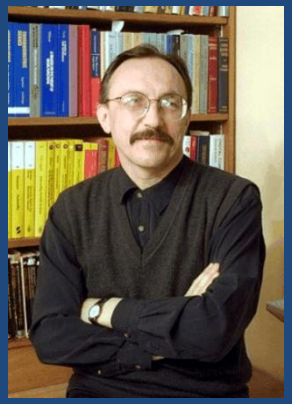
IDR is typically collaborative and involves people of disparate backgrounds. **It may take extra time for building consensus and for learning new methods, languages, and cultures.**

****



Science and Technology Centers

"Create a shared intellectual space, integral to the center's activities, providing a collaborative research environment that crosses disciplinary and institutional boundaries"

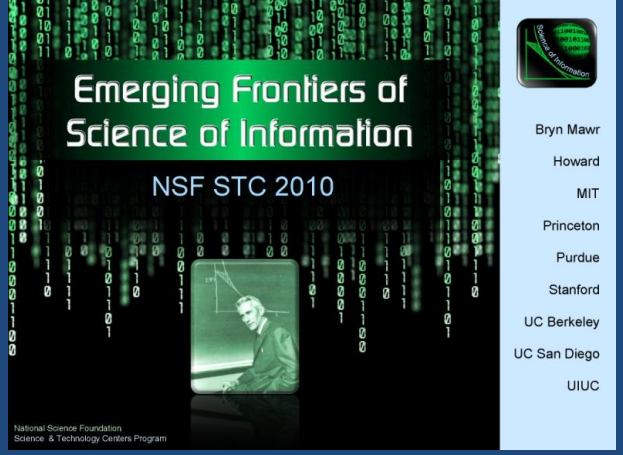


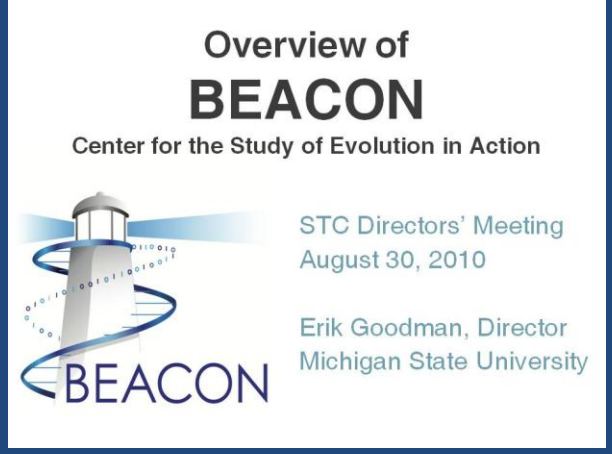
Wojciech Szpankowski, Purdue University
Director, Center for Science and Information (an NSF STC)

Science and Technology Centers

- Open competitions, currently 17 Centers, all areas of NSF
- Each STC is an extended partnership led by one institution

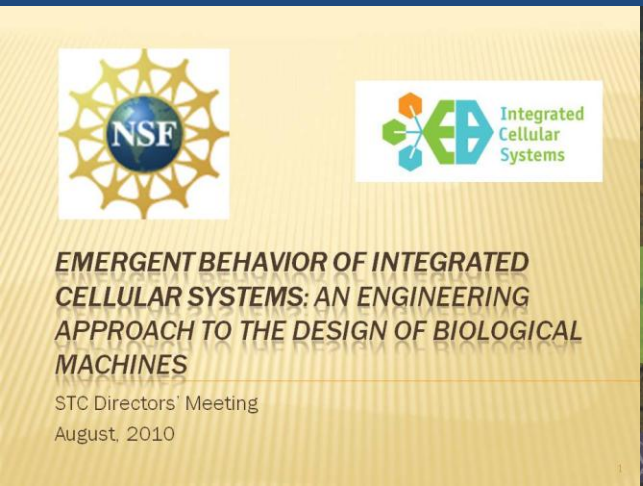
- **Many of the STCs focus on sustainability themes:**
  - National Center for Earth-Surface Dynamics - 2002
  - Center of Advanced Materials for the Purification of Water with Systems - 2002
  - Center for Remote Sensing of Ice Sheets - 2005
  - Center for Multi-Scale Modeling of Atmospheric Processes - 2006
  - Center for Coastal Margin Observation and Prediction - 2006
  - Center for Microbial Oceanography Research and Education - 2006
  - Center for Dark Energy Biosphere Investigations - 2010
  - Center for Energy Efficient Electronics Science - 2010

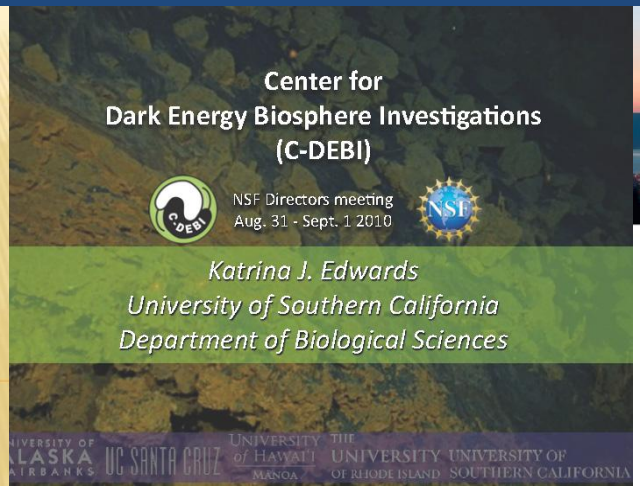


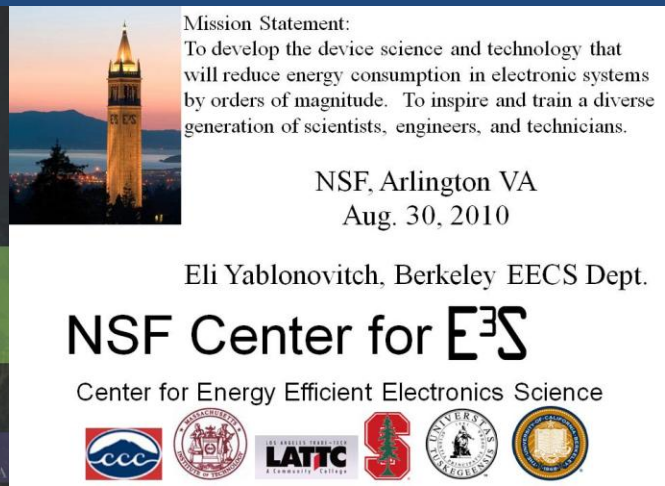


Five new STCs established in 2010

New solicitation in FY 2011







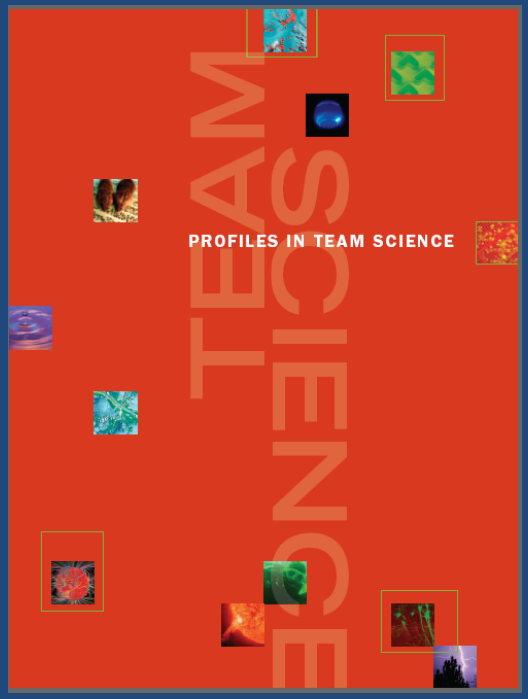
NSF Office of Integrative Activities

http://nsf.gov/dir/index.jsp?org=OIA

****

Profiles in Team Science

http://depts.washington.edu/teamsci/welcome.html



****

AAAS Blue Ribbon Panel Report on STC Program Outcomes

– for release early 2011

Energy Efficient Electronics Science STC

UC Berkeley and partners

The amount of power required by electronics will continue to grow dramatically unless we make some **fundamental changes to the physics, chemistry, and materials and device science** that underlie information processing technologies

To reduce the energy requirement of electronics, **researchers will focus on the basic logic switch**, the decision-maker in computer chips. The logic switch function is primarily performed by transistors, which demand about 1 volt to function well.

"The transistors in the microprocessor are what draw the most power in a computer. When you feel the heat from under a laptop, blame it on the transistors" – *Eli Yablonovitch*

It's Time to Reinvent the Transistor!

Thomas N. Theis* and Paul M. Solomon

IBM Research, T. J. Watson Research Center, Post Office Box 218, Yorktown Heights, NY 10598, USA.

1600 26 MARCH 2010 VOL 327 SCIENCE www.sciencemag.org

Energy Efficient Electronics Science STC

UC Berkeley and partners

Develop the device science and technology that will reduce energy consumption in electronic systems by orders of magnitude

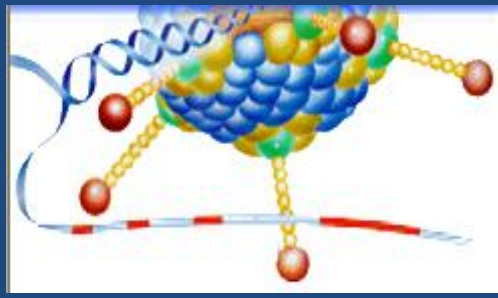
An electronic circuit could operate well on as little as a few mv.

A thousand-fold reduction in voltage requirements translates into a million-fold reduction in power consumption

- Nanoelectronics Develop semiconductor millivolt switching
- Nanomechanics Develop low voltage nanomechanical switches
- Nanomagnetics Use the technology of nanomagnets to create low energy logic switches
- Nanophotonics Develop optical communication that relies on only a few photons per bit

WaterCAMPWS STC

University of Illinois and partners

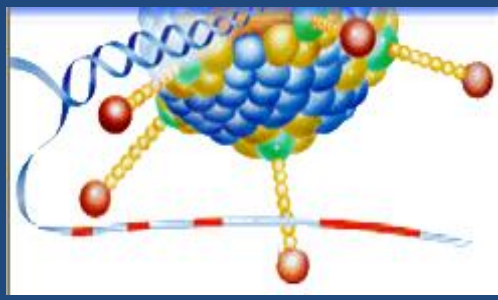


Advance the fundamental understanding of the interaction of materials with water and its constituents

The grand challenge: use this enhanced understanding of aqueous interfaces to guide the development of new materials and systems and inspire revolutionary new approaches for water purification

WaterCAMPWS STC

University of Illinois and partners

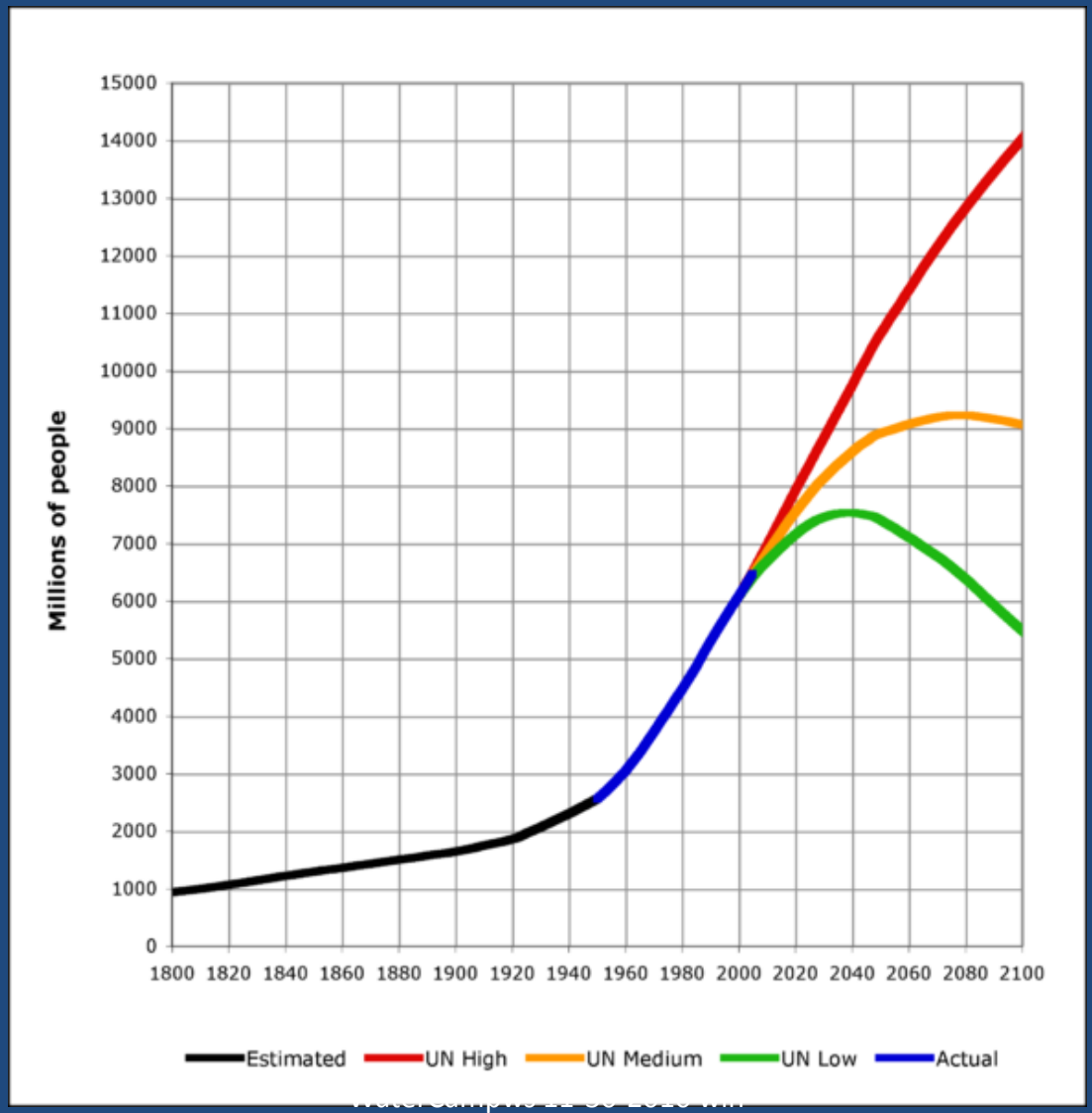


New water purification technologies focused on the nexus between **Water and Energy** and **Water and Health** have the potential to reduce the quantities of energy and chemicals now used to treat water and can create new methods to **desalinate, reuse, decontaminate, and disinfect** waters, enabling nations to gain new waters for human use from different types of source waters, including those that are not now considered usable.

[Source: Shannon, M. A., P. W. Bohn, M. Elimelech, J. G. Georgiadis, M. J. Mariñas, and A. M. Mayes, "Science and Technology for Water Purification in the Coming Decades," Nature 452, 301-310, 2008.]

World Population from 1800 to 2100

(Based on UN 2004 projections)



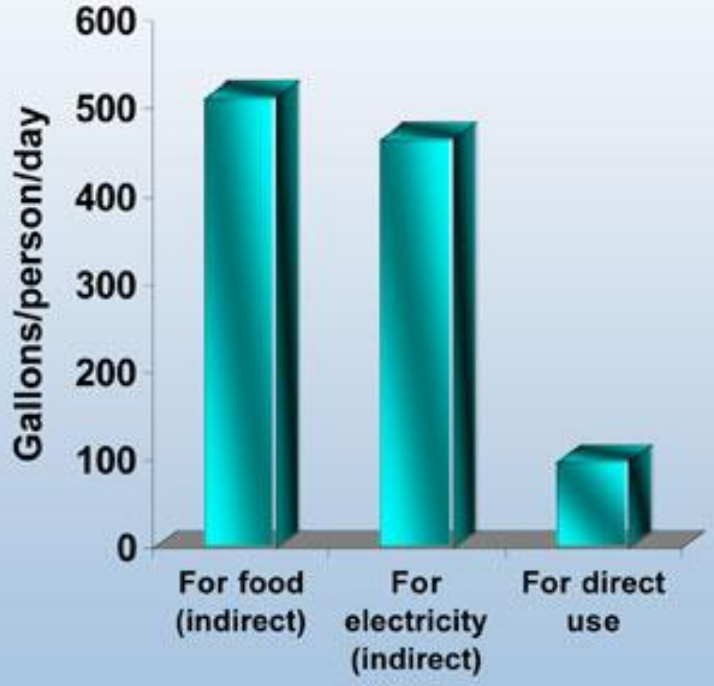
Water Sustainability

thanks to Paul Bishop – NSF Environmental Engineering Program

- Much of the world's population is rapidly running out of water, both potable and non-potable
  - Global water consumption is doubling every 20 years
  - The UN expects demand to outstrip supply by >30% by 2040
- We must find "new" sources of water or ways to conserve or reuse what we now have
- In a sense, all of our water is reused
  - -- The "purity" of our water supplies should match its intended use
- Energy is a major user of water and needs to be controlled
  - -- As readily available water is depleted, the alternatives may have much larger energy and resource requirements
  - -- Life Cycle Assessment is essential

Energy Requires Water

Water used to produce household electricity exceeds direct household water use



GALLONS PER PERSON PER DAY

- 510 for food production
  - includes irrigation and livestock
- 465 to produce household electricity
  - Range: 30 to 600 depending on technology
- 100 direct household use
  - includes bathing, laundry, lawn watering, etc.

Source: derived from Gleick, P. (2002). *World's Water 2002-2003.*

Energy and Water are Inextricably Linked

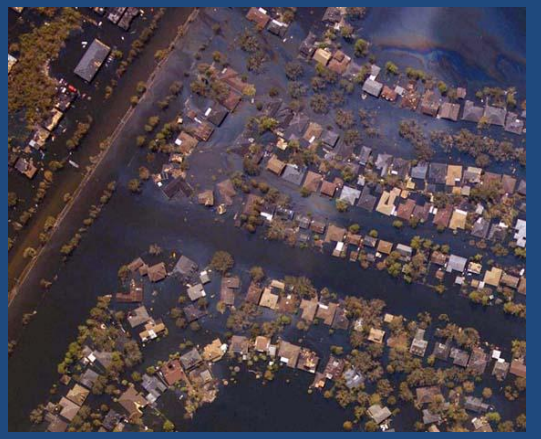
Water for Energy ***and*** ***Energy for Water***

Energy and power production requires water:

- Thermoelectric cooling
- Hydropower
- Energy minerals extraction/mining
- Fuel production
- Emission controls

Water production, processing, distribution and end-use requires energy:

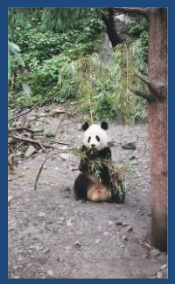
- Pumping
- Conveyance and Transport
- Use conditioning
- Surface and Groundwater



Rapid, multi-faceted global change is challenging human well-being

Ships take to Arctic Ocean as Sea Ice Melts. Journey time between Europe and China can be reduced by half. MSNBC.com

Science, Engineering, and Education for Sustainability (SEES)



NSF SEES Portfolio Overview

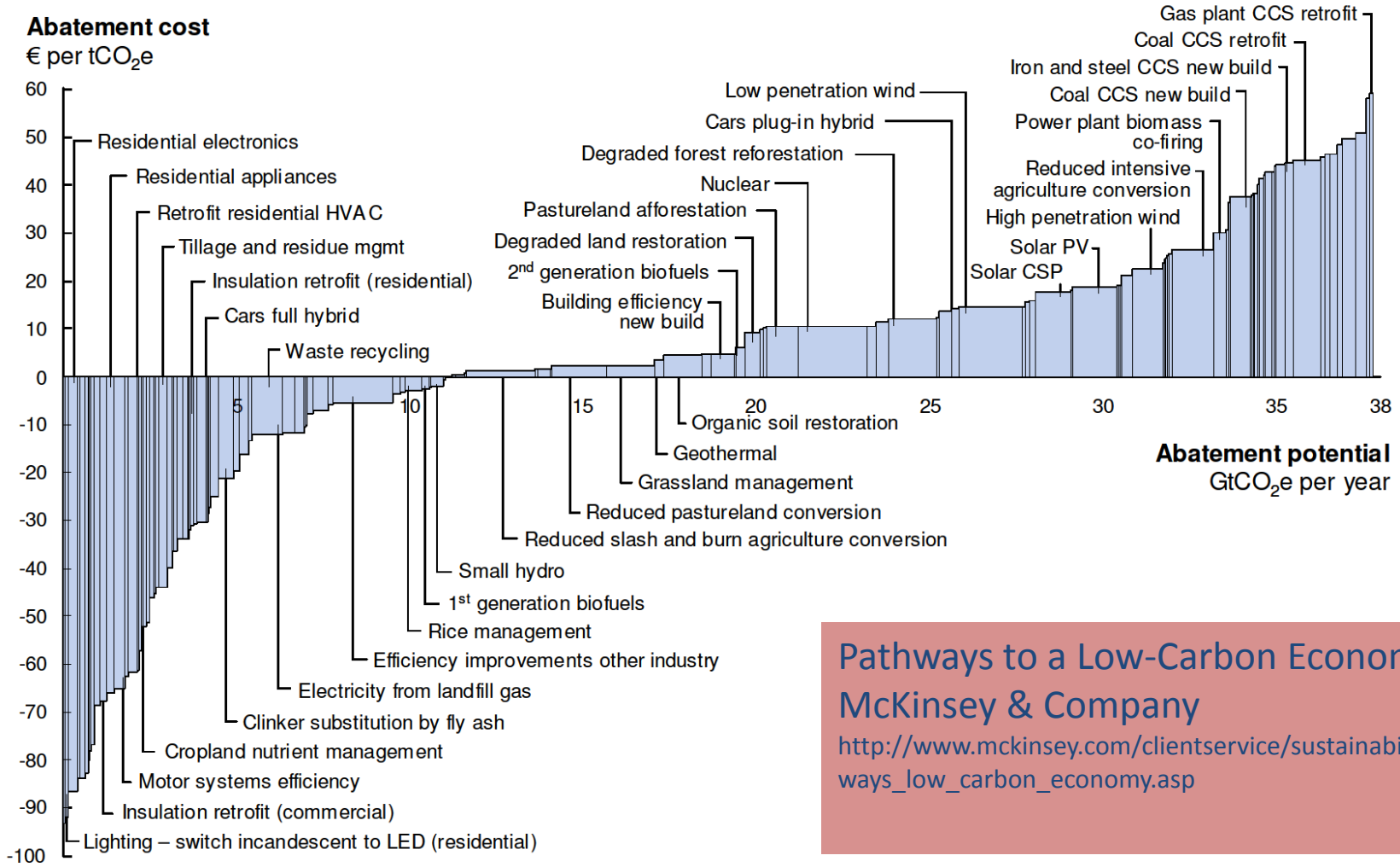
thanks to

Dr. Tim Killeen, Assistant Director for GEO/NSF

On behalf of the complete AD/OD team


Energy consumption growing
today
… to unprecedented demands
2030

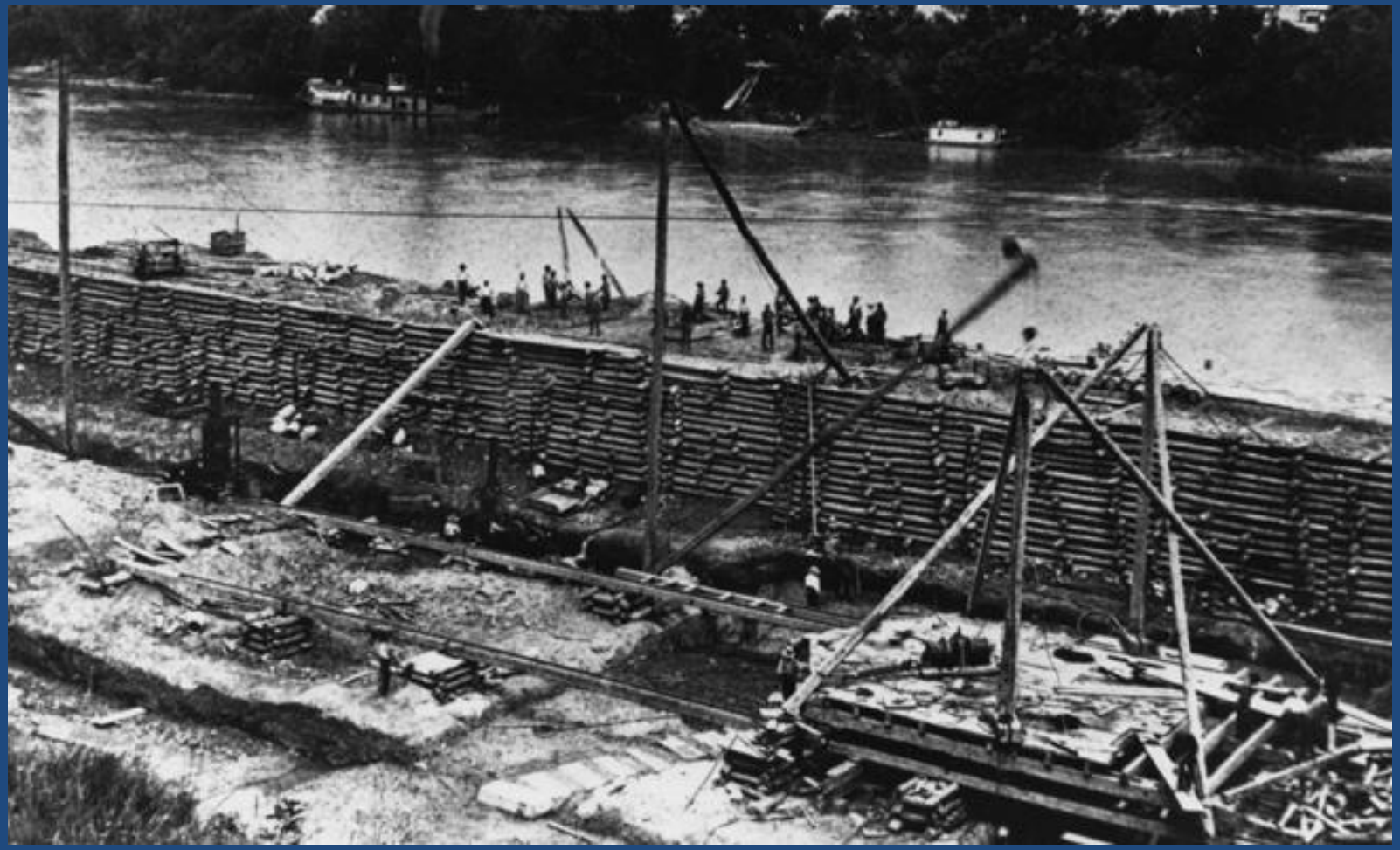
GHG abatement: beyond business-as-usual 2030



Pathways to a Low-Carbon Economy
McKinsey & Company
http://www.mckinsey.com/clientservice/sustainability/pathways_low_carbon_economy.asp

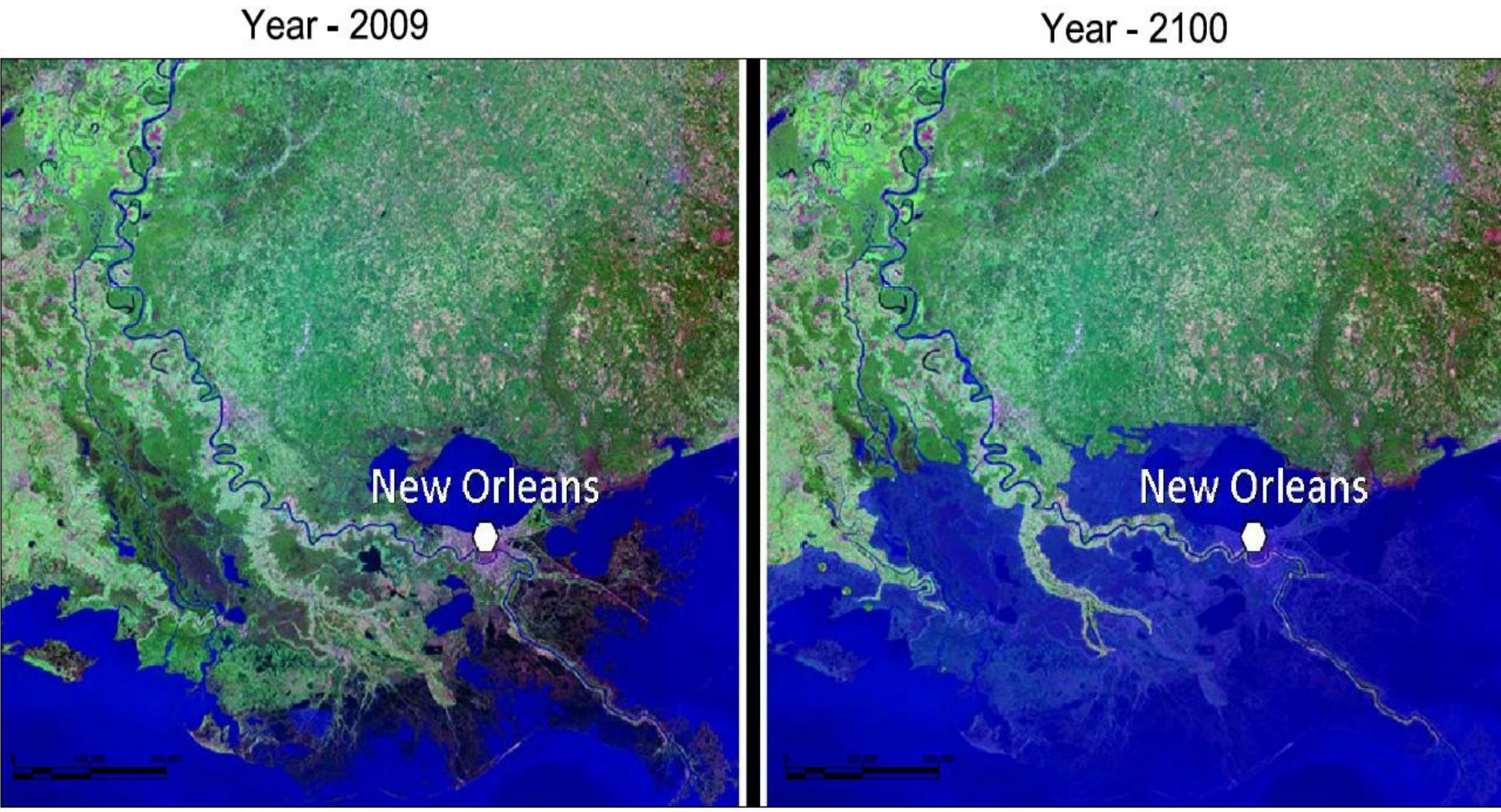
Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

Mississippi River & Tributaries



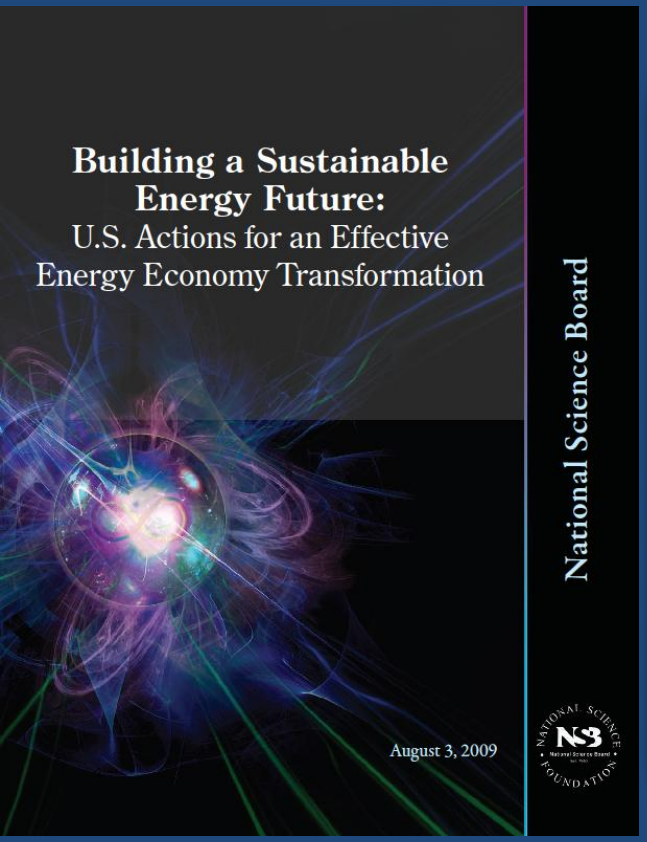
The Flood Control Act of 1928 put flood control on par with other major projects of its time with the largest public works appropriation ever.

Changes that can affect us

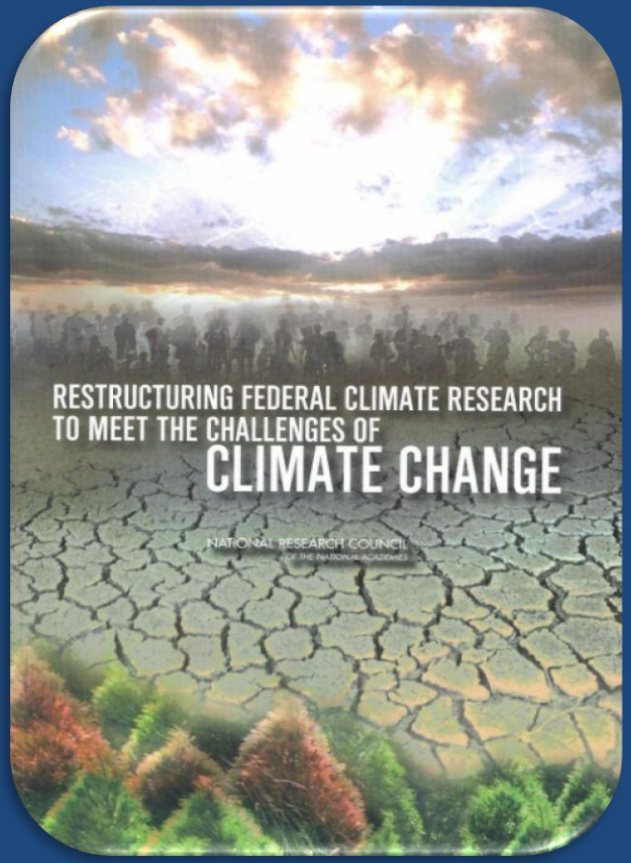


Map: Blum, M.D., and H.H. Roberts (2009), Drowning of the Mississippi delta due to insufficient sediment supply and global sea-level rise, *Nat. Geosci.*, 2, 488-491.

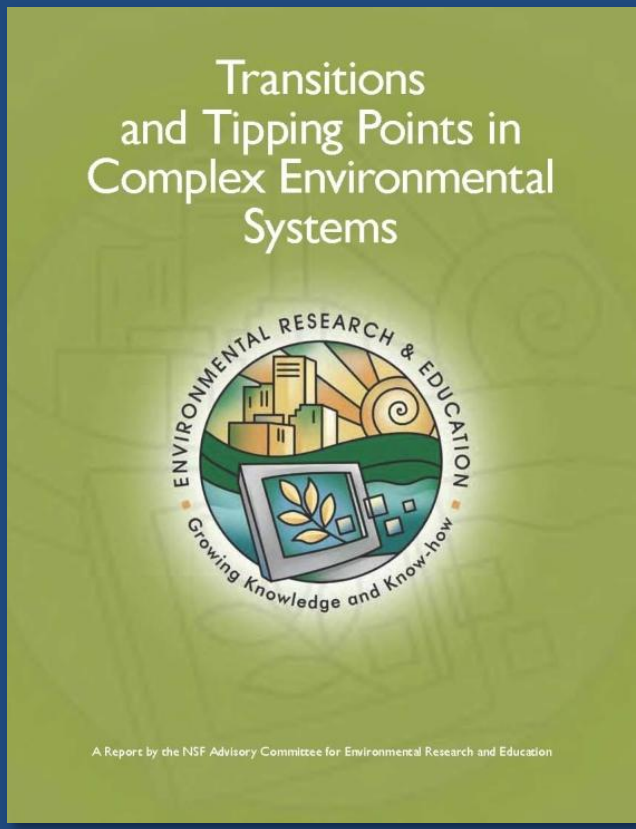
Guidance from the S&E Community



NSB 2009



NRC 2009



NSF AC-ERE 2009

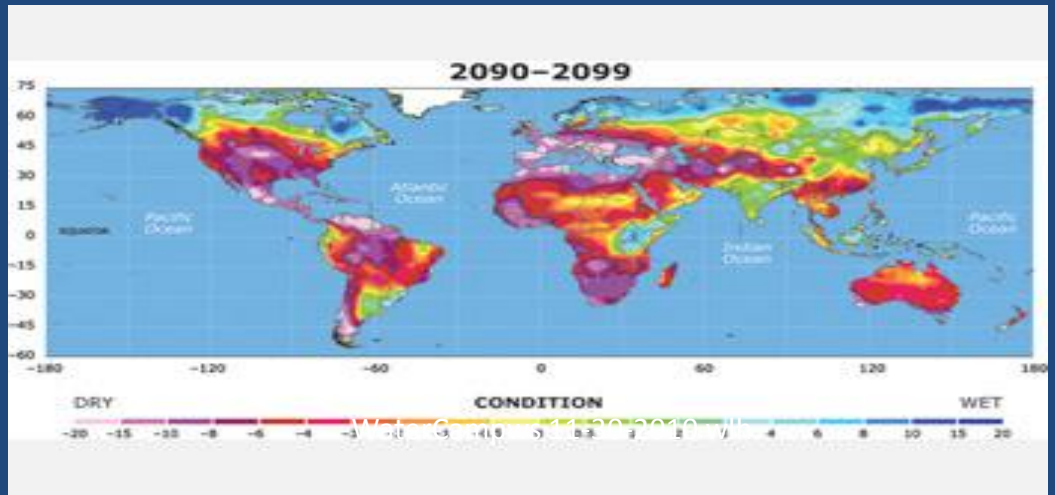
Sustainability Science & Engineering

- National Academy of Sciences definition of SSE:

  "The interactions between natural and social systems and how those interactions affect the challenge of **sustainability**:

  …meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems"

  www.pnas.org/site/misc/sustainability.shtml



Science, Engineering, and Education for Sustainability

SEES will generate the discoveries in climate and energy science needed to inform societal actions for environmental and economic sustainability

- New areas of research that help close key gaps in the knowledge base
- New models for research, specifically employing integrative, systemic approaches
- New integrated understanding of the interplay of environment, energy, and the economy
- Improve our capabilities for rapid response to extreme events

SEES portfolio totals $765.5 million in FY 2011 request

SEES Major Aims

- **Support research and education** to inform global community sustainability
- **Build connections** between current projects and create new nodes of activity
- **Develop personnel** needed to understand complex issues of sustainability

SEES Portfolio Focus Areas

- Research at energy-environment-society nexus
- Novel energy production, harvesting, storage, transmission, and distribution technologies
- Corresponding adoption, socioeconomic, and policy issues
- Innovative computational science and engineering for monitoring, understanding and optimizing life-cycle energy costs and carbon footprints of natural, social, built systems
- Study of societal factors such as vulnerability and resilience, and sensitivity to regional change

SEES Organizational Overview

- Established FY10, planned to continue through FY15
- Core activities plus targeted solicitations

Organizational Structure

- NSF-wide – includes all research and education units
- Senior leadership by Assistant Directors/Office Heads
- Working groups of Program Directors
- Interagency working groups, with potential for MOUs/MOAs, interagency solicitations
- NSF engagement with international partners, such as the EU

FY10: Climate Research Initiative (CRI) – starting point for SEES

- Emphasis on climate and environment, including human sciences
  - Water, Sustainability, and Climate (WSC)
  - Ocean Acidification (OA)
  - Dimensions of Biodiversity (DB)
  - Climate Change Education Program (CCEP)
  - Regional and Decadal Earth System Modeling (EaSM)

Water Sustainability and Climate (WSC)

NSF Solicitation # 10-524

Water Sustainability and Climate

- The goal is to understand and predict the interactions between the water system and climate change, land use, the built environment, and ecosystem function and services through place-based research and integrative models.
- Multi-directorate solicitation involving the Directorates of Engineering, Geosciences, Biology, and Social, Behavioral and Economic Sciences
- Three categories:
  - Small exploratory or incubation grants to develop teams, identify sites, hold workshops and develop plans for establishment or operation of a study site, 1-2 years and up to $150,000.
  - Place-based observational and modeling studies, up to 5 years in duration and for a maximum of $5 million for each award.
  - Synthesis and integration grants that will only use existing data to integrate and synthesize across sites, 3-5 years in duration and for a maximum of $1.5 million for each award.

Water Sustainability and Climate

- In 2010, a total of 16 awards were made
  - 10 Category 1 Workshop Planning grants
  - 3 Category 2 Observatories and Modeling grants
    - Extreme events impacts on water quality in the Great Lakes: Prediction and management of nutrient loading in a changing climate
    - Regional climate variability and patterns of urban development – Impacts on the water cycle and nutrient export
    - Climate change, shifting land use, and urbanization in a Midwestern agricultural landscape: Challenges for water quality and quantity
  - 3 Category 3 Modeling grants

SEES Focal Points for FY11

- Enhance existing SEES portfolio
- Support sustainable energy research and its socioeconomic, environmental implications.
- Respond to NSB Sustainable Energy report
  - Systems approaches to research programs, education and workforce development, public awareness and outreach
  - Partnerships with other agencies, states, universities, industry, international organizations

International Leadership

- Partnerships for International Research and Education
- International Council of Scientific Unions (ICSU)

Grand Challenges in Global Sustainability Research

- **Forecasting**
- **Observations**
- **Thresholds - abrupt change**
- **Responses - institutional, economic and behavioral changes**
- **Innovation**

To meet these challenges we need

- **Enhanced capacity to undertake interdisciplinary research**
- **A new generation of scholars taking a systems approach to problems of global sustainability**

NSF's Unique Role

- Best connected of any government and/or industry to a spectacular intellectual resource - U.S. Colleges and Universities!
  - A coalition of willing participants
- Long history of supporting areas of research that need to contribute to sustainability
- We have made a start!
  - -- Innovator in fostering interdisciplinary research
  - -- Productive relationships with Federal agencies and International partners
  - -- CRI Investments; SEES Portfolio investments

OMB-OSTP S&T Priorities for FY12

- Moving toward a clean energy future to reduce dependence on energy imports while curbing greenhouse gas emissions
- Understanding, adapting to, and mitigating the impacts of global climate change
- Managing the competing demands on land, freshwater, and the oceans for the production of food, fiber, biofuels, and ecosystem services based on sustainability and biodiversity

And what if our idea doesn't fit one of NSF's boxes??

Interdisciplinary Research Portal
http://www.nsf.gov/

A guide to the mechanisms through which NSF promotes and supports interdisciplinary research – information on where and how to submit an interdisciplinary proposal.

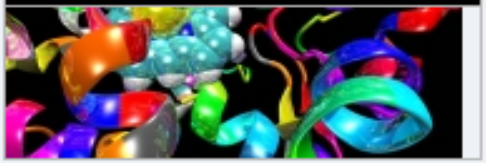
A primary purpose is to assist investigators in submitting an ***unsolicited*** interdisciplinary proposal for which there may not be a natural "home" in one of the existing NSF programs.

National Science Foundation
WHERE DISCOVERIES BEGIN

SEARCH
NSF Web Site

HOME | FUNDING | AWARDS | DISCOVERIES | NEWS | PUBLICATIONS | STATISTICS | ABOUT | FastLane

Interdisciplinary Research



Introduction

- Definition
- Sources of Support
- Contact Options
- Points of Contact
- What To Submit
- FAQs

Introduction to Interdisciplinary Research

NSF has long recognized the value of interdisciplinary research in pushing fields forward and accelerating scientific discovery. Important research ideas often transcend the scope of a single discipline or program. NSF also understands that the integration of research and education through interdisciplinary training prepares a workforce that undertakes scientific challenges in innovative ways. Thus, NSF gives high priority to promoting interdisciplinary research and supports it through a number of specific solicitations. NSF also encourages researchers to submit unsolicited interdisciplinary proposals for ideas that are in novel or emerging areas extending beyond any particular

A virtual reality wall displays interactive visualizations of proteins.

Your "Unsolicited" Interdisciplinary Research Ideas are Welcome!

who to contact

- Any NSF program officer
- A program officer listed on the IDR website
- Tom Russell in OIA – trussell@nsf.gov

or

- email an inquiry to idr@nsf.gov
- call (703) 292-4840

http://www.nsf.gov/ *Interdisciplinary Research*

In closing…
One view of the scientific enterprise

"The four corners of deceit: government, academia, science and media. Those institutions are now corrupt and exist by virtue of deceit. That's how they promulgate themselves; it is how they prosper."

Quoted in Nature, 9 September 2010

Alternatively…

"After four decades of studying these issues, I've concluded that energy is the core of the environment problem, environment is the core of the energy problem, and resolving the energy-economy-environment dilemma is the core of the problem of sustainable well-being for industrial and developing countries alike."

- John Holdren

Thank You!

lhaworth@nsf.gov